Outcomes of decompressive craniectomy in adults with severe traumatic brain injury – The Groote Schuur Hospital experience

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(Publication-ready format)

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Declaration

This dissertation is based on independent work performed by the candidate (JMN Enslin) and neither the work nor any part of it has been, is being, or is to be submitted for another degree to any other university.

This work has not been reported or published prior to registration for the abovementioned degree.

Abstract

Object. The aim of this study was to assess outcome following decompressive craniectomy in adults with severe traumatic brain injury (TBI) in a South African neurosurgical unit.

Methods. During a 78 month period (January 2005 – June 2011), 76 patients that underwent decompressive craniectomy for TBI in an attempt to lower raised intracranial pressure (ICP) were reviewed. All were older than 14 years and mass lesions were included. Thirty nine point four percent of the patients sustained blunt, low velocity injuries to the head and 19% were involved in motor vehicle accidents. Unilateral hemi-craniectomies were carried out in 81% of patients and 54 (75%) were done as primary decompressive craniectomies. Survivors were followed up for a period of at least six months and functional outcomes were measured using the Glasgow outcomes score. To simplify outcomes the patients were then dichotomised into outcome groups of good (GOS 4 and 5), and poor (GOS 1-3).

Results. At six months follow up 24 patients (33.3%) had a good outcome (GOS 4 or 5) and 48 patients (66.7%) had a poor outcome (GOS 1-3). 32 patients (44.4%) died (GOS 1). There were 16 survivors in the poor group. Sixty percent of survivors had a good outcome after decompressive craniectomy. Eighteen patients underwent secondary decompressive craniectomies and 54 (75%) primary decompressive craniectomies. Thirty-five percent of patients that underwent primary decompressive craniectomy had a good outcome, versus 38% in the secondary decompression group. Mortality was slightly higher in the primary decompression group (43%) than the secondary group (33%). Factors that showed significant correlation with outcome were age, admission GCS and good response of ICP to decompressive craniectomy. Complications were encountered in 18% of patients with sepsis being the most common (11%).

Conclusion. Decompressive craniectomy was associated with a functional outcome that was better than expected in patients with severe TBI and should still form part of salvage therapy in adults with TBI and elevated ICP.

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Protocol

Title:

Outcomes after Decompressive craniectomy in adult traumatic brain injury: The Groote Schuur experience

Abstract

Decompressive craniectomy is a surgical procedure done to reduce intracranial pressure. It forms the last tier in the Brain Trauma foundation and other guidelines in the management of severe traumatic brain injuries, for management of medically refractory increased intracranial pressure. The purpose of this study is to evaluate the outcomes of patients with severe head injuries at Groote Schuur Hospital, who underwent decompressive craniectomies. The Glasgow Outcome score will be determined at three months and at six months after discharge from ICU. It is however important to acknowledge that patient outcomes may continue to improve after six months. The data gathered will then be compared to that of similar trials in Europe and Australia. This will allow the researchers to compare and decide whether this is a worthwhile procedure. This study is especially important at present as serious doubt arises from the recently completed DECRA trial in Australia as to the benefits of decompressive craniectomy in the patient with severe head injury.

Study Problem

What is the functional outcome of patients with traumatic brain injuries that underwent decompressive craniectomies, at Groote Schuur hospital?

The purpose of this study is to determine the outcome of decompressive craniectomy in the population of severe traumatic brain injury, treated at Groote Schuur Hospital.

Does the experience at Groote Schuur hospital mimic that of the DECRA and many European studies?

Rationale/Relevance of the Project

Decompressive craniectomy was done for traumatic brain injury since the earliest of times. It is only recently however that this practice has been performed routinely in the management of patients after traumatic brain injury with poorly controlled intracranial pressure. For decompressive craniectomy to be considered for raised intracranial pressures, one needs to know what the intracranial pressure is. Therefore this practise is closely related to the introduction of intracranial pressure monitors. Before the use of intracranial pressure monitors the decision to decompress was based solely on clinical grounds and the subjective interpretation of intracranial pressure on the CT scan image. The development and regular use of intracranial pressure monitors initiated a vast array of research opportunities worldwide into the physiology and management outcomes of traumatic brain injuries.

A multicentre, randomised controlled trial (DECRA)[1] was recently published on the outcomes of decompressive craniectomies in the management of traumatic brain injury in adults and a further, larger, trial is underway [RESCUE ICP][2]. There are studies published in the international literature that states more than 60% good outcomes after decompressive craniectomy. In South Africa the authors have the opportunity to study large numbers of patients with traumatic brain injuries. The mechanism of these injuries however differ widely from that of the American and European population: South African neurosurgery units deal with larger numbers of low velocity brain injuries (blunt trauma; and panga/ machete injuries or hand assault), as well as high velocity injuries (gunshot wounds; High speed motor vehicle accidents).

It is this fact that leads to the importance of this study. The authors need to determine what the outcome of decompressive craniectomy is at Groote Schuur hospital, therefore adding valuable information to management of traumatic brain injury in South Africa, and indeed adding to the world wide knowledge bank and improve understanding and management of traumatic brain injuries.

Literature Review

A detailed electronic literature search was done, using PubMed® and MEDLINE medical databases as well as Google Scholar® search-engine. Dates of the search were 1948 to 2011 January. Keywords for the search: *decompressive craniectomy; physiology; intracranial pressure; traumatic brain injury; outcome.*

A review of the related literature gathered during this search was done.

Decompressive craniectomy is firmly entrenched as the final step in the treatment of persistently raised intracranial pressure, in the setting of severe traumatic brain injury.

According to the Monro-Kelly doctrine, intracranial contents are made up of the following three components: fluid (CSF), brain matter and blood[3]. It is therefore a sensible option to enlarge the 'container' if any of the three main components enlarge, or if another component (tumour, blood or interstitial oedema) is added to the rigid confines of the cranium. This assumption has for many years formed the basis of modern neurosurgical thinking. It is however recently (March 2011) that this "gold-standard" of treatment has been veiled under a shroud of doubt. With the publication by Cooper and colleagues in the long awaited DECRA trial[1], all certainty in the – once cast in stone – approach to persistently elevated intracranial pressure algorithm, is in doubt. In their study Cooper et al, found that although the intracranial pressure is lowered in the decompressed group of patients, their long term (6 month) outcome as well as mortality is not better than that of the medically treated cohort. Shortcomings of this trial was however the low threshold for initiating treatment – 20mmHg ICP, as well as the short period that pressure is elevated before intervention was planned. The brain trauma foundation guidelines[4] used in the Groote Schuur unit as well as most American units states 25mmHg as the cut-off for initiating aggressive medical or surgical treatment of elevated ICP. It is also well understood that intracranial pressure is not static and that variations of pressure this high does not always need aggressive intervention. It is however persistent elevation of intracranial pressure above 25 mmHg that requires intervention[4].

It is of importance to note that in a Cochrane database meta-analysis of available literature, before publication of recent DECRA trial, there proved to be no difference in outcome between the decompressive craniectomy group and the medically managed group of severe head injury patients.[5]

Based on our own experience in Groote Schuur Hospital, with a larger group of patients with severe head injury compared to the European units, the author of this study is of opinion that there is not such a poor outcome associated in our experience for a similar group of patients. There is however no scientific proof of this opinion. This is therefore why this study is now, more than ever, important. Guided by the information accumulated by this study, as well as the RESCUE ICP trial[6], still underway, Neurosurgery practice in South Africa, as well as over the world, will be able to better determine the indications, risks and complications associated with decompressive craniectomies for the treatment of severe head injured patients. Only with proof that there is a statistically significant improvement in outcome after decompressive craniectomy can this procedure remain to be part of the protocol for treatment of severe head injuries.

Specific Study Objectives

1 Primary objective: What is the functional outcome of decompressive craniectomy at GSH?

2 Secondary objectives:

2.1 Determine indications for decompressive craniectomy in this unit

2.2 Determine timing from admission to decision to do decompressive craniectomy

2.3 Is the decision to do decompressive craniectomy based on a specific intracranial pressure or on clinical decision-making?

2.4 Determine duration of ICP monitoring and pressure trends during the ICU stay

2.5 Measure the clinical outcomes of the patients that underwent decompressive craniectomy, using the Glasgow outcome score at three, as well as at six months follow up.

2.6 Document complications experienced as a result of the decompressive craniectomy

2.7 Compare results of this trial with those of similar trials in other countries (DECRA and RESCUE ICP)

Research Methods

Study design

This will be a historical cohort-study. All patients that underwent decompressive craniectomies at Groote Schuur hospital during the time period 2005 – 2011 will be the study population. The records of these patients will be used to gather the data.

Subjects

All patients undergoing decompressive craniectomy after traumatic brain injury at Groote Schuur hospital between January 1 2005 and June 31 2011 will be included in this study. The patients undergoing decompressive craniectomies for non-trauma related reasons (i.e. Malignancies, stroke) will be excluded from this study. Patients under the age of 14 will also be excluded from this study as these patients are not treated at Groote Schuur Hospital. Those patients in whom there is no objective assessment data in the medical folders will also be excluded from the cohort so as to ascertain objectivity and reproducibility in data collection.

Sampling: All patients with traumatic brain injury that underwent decompressive craniectomy at Groote Schuur Hospital in the period January 1 2005 to June 31 2011. These records will be reviewed. No patients will be assessed again.

All data from patients in the above-mentioned group will be use for this study. No personal data will be collected and no mention to patient demographics will be used or published.

No randomization will be done as this is solely a retrospective record review. No intention to treat analysis or intervention will be done.

Data collection

A thorough search of the electronic database kept of the Neurosurgery Intensive Care unit at Groote Schuur Hospital will be done by hand, thereby identifying all patients that underwent decompressive craniectomy at Groote Schuur Hospital. A hand search will be done of the operative registry at Groote Schuur hospital to make sure that no cases of decompressive craniectomy are missed.

The researcher will then manually go through each of the subject's hospital records. Timing of the decompression, intracranial pressures before and in the period after decompressive craniectomy will be documented. The clinical outcome in the form of Glasgow outcome score (**see Addendum A**) will be determined from the records as kept by medical staff of the Neurosurgery department at Groote Schuur Hospital. The subjects that passed away will be indicated as such and also the cause of death will be indicated in the data collection process.

The Glasgow outcome score will be used. The test will be scored at three months and six months post intervention. This is comparable to the protocols of similar European studies.

It is important to keep in mind that Human Immune-deficiency Virus can also be a confounding factor in the outcome of subjects after decompressive craniectomy, especially in relation to infective causes of death. In those patients where HIV-status was known an entry of this will also be made in the data-collection sheet. No identifiable data will be coupled to these entries to preserve confidentiality.

All the data collected during this study will then be entered into Excel database program and analysed using Graphpad® statistical analysis software for Windows. The advice and assistance of the biomedical statistician at the Medical faculty of University of Cape Town will be requested in the analysis of the data obtained. Probability and reliability of these data will be determined.

Intervention

This will be a retrospective record review. No intervention is planned on the study population.

Statistical considerations

All the patients that underwent decompressive craniectomy during the period as mentioned above will be used during the analysis. It is estimated that there will be between 80 and 100 subjects for incorporation into this study. The data will be inserted into the database as described in the data collection section above. The median values of intracranial pressure before and after decompressive craniectomy will be determined. The median Glasgow outcome score (**Addendum A**), for all the subjects will be determined day after surgery, on discharge from intensive care as well as on follow up at neurosurgery outpatient department will be determined. To measure results against that of European investigators a Glasgow outcome scores will be determined at 28 days as well as at 6 months post decompression. Outcomes will be divided into two groups – good (Score of 3 or 4) and poor (score 1 or 2 and death). A student's t-test as well as X_2 analysis will be done as part of the analysis to analyse the data captured. This will be done to replicate the European data to compare the results.

Ethical Considerations

Patient privacy and confidentiality is of the utmost of importance to the researcher. Care will be taken not to connect any personal or identifiable characteristics of the subjects to the data collected or published. No photo or video data of any subject will be needed. No personal medical data will be connectable to any of the subjects during this study. All subjects in this retrospective study were treated as per best medical evidence and judgement of the Neuro-intensive care team at Groote Schuur Hospital. No randomisation is done. No intervention is withheld or performed different from usual practise at this unit for the purpose of this study.

This protocol will be presented to the surgical research committee at Groote Schuur Hospital as well as the Ethics committee of the University Of Cape Town Medical School. The protocol will be implemented after clearance was obtained by these boards.

Consent form

No personal data of any patient used in this study will be used. As this is a retrospective record review with no intervention or implication to the subjects used during this study, no consent forms will be needed from this study population.

Privacy of information

This is a retrospective analysis of patients undergoing decompressive craniectomies at Groote Schuur Hospital. There will therefore be no association between the data and the individual patients. No identifiable characteristics will be used in the analysis or the publication of this study.

Work Plan

	May	June	July	August	September	October	November
Submission to ethical committee			*				
Collection of data			*	*			
Writing of research report				*	*	*	

Presentation research day						*	

Budget

The author will be using his own computer as well as own transport during the study. The patients are reviewed at the outpatient department of Groote Schuur Hospital as per discharge and routine follow-up protocol. There will be no financial implications to the University or the Government of the Western Cape.

Research team

The research for this study as well as the collection of data will be done by the author himself. The follow up of the study subjects have been, and will be done by the registrars and consultants of the department of neurosurgery at Groote Schuur hospital as per their routine outpatient clinic duties. Professor PL Semple from department of Neurosurgery at Groote Schuur hospital is my study leader.

Dissemination Plan

Submission of protocol to ethical committee of University of Cape Town	July 2012
Collection of patient data from folders at Groote Schuur Hospital	July - August 2012
Statistical analysis of data	August 2012
Presentation at UCT Surgery research day	November 2012
Compilation and submission of article for journal publication	April 2013

Reference list

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Addendum A

The Glasgow Outcome Scale

1. Dead
2. Vegetative State (meaning the patient is unresponsive, but alive)
3. Severely Disabled (conscious but the patient requires others for daily support due to disability)
4. Moderately Disabled (the patient is independent but disabled)
5. Good Recovery (the patient has resumed most normal activities but may have minor residual problems)

Outcomes of Decompressive Craniectomy in Adult TBI: a Literature Review

Introduction

Over the past 20 years much has been published on management of adults with traumatic brain injury (TBI). Intracranial pressure monitoring and brain oxygenation monitoring have made a great impact in the management of traumatic brain injuries in adults. The combination of these two has been used in the last 6 years in Groote Schuur Hospital and Red Cross Children's Hospital to guide decision making in severe TBI patients.

As will be seen in a review of the published literature, there are not many advocates who doubt whether decompressive craniectomy decreases intracranial pressure (ICP). However, the doubts that are raised, are whether doing a decompressive craniectomy improves not just neurological-, but functional- and psychological- outcome,[1] or whether it may lead to an increased burden on family and the medical system by leaving a patient, who would otherwise have died, in a persistent vegetative state.[2]

The purpose of this literature review is to analyse and then synthesise the vast amount of literature on the topic of decompressive craniectomy as part of the management options in treating patients with severe TBI.

Methods

A thorough literature search was compiled using the MEDLINE database from 1948 – (Week 2) December 2012, as well as Google Scholar search engine. A total of 137 relevant articles were found of which 132 were in the English Language. One hundred and one articles were evaluated for this literature review after all those investigating children and animals were excluded. Additional references were obtained from reference lists used in these relevant articles, especially the four articles yielded under outcomes in decompressive craniectomy. The literature on decompressive craniectomy in cerebro-vascular incidents, as well as those studies looking at decompressive craniectomy in children was excluded. A single meta-analysis in the Cochrane review database was also found and included. The outcomes were compared using a dichotomised Glasgow Outcome Score (GOS) as Good (GOS 4 or 5) or Poor (GOS 1-3). In those studies where outcomes were not reported using this scale, all efforts were made to interpret it while using GOS as far as scientifically possible to attain comparability. Key words used were: Decompressive craniectomy; Traumatic brain injury; outcomes; adults; refractory elevated intracranial pressure; complications.

Definitions

Decompressive craniectomy is the term used to describe the surgical procedure wherein a craniectomy is performed with the aim to reduce intracranial pressure. This craniectomy has to fulfil certain size and position criteria to be effective. There are two anatomical area's where a decompressive craniectomy is performed, namely **bifrontal craniectomy** – where the bone covering both frontal lobes, as well as both temporal poles, are removed from posterior to the coronal suture, up to the middle- and anterior-cranial fossa floor bilaterally, usually as a single piece of bone. The other common procedure is a **hemi-craniectomy**. Here the craniectomy is performed on a single side and the bone covering the parietal-, frontal-, as well as temporal-pole is removed. The aim is to go as low as the middle-, and anterior-cranial fossa floor.

Primary decompression (also known as early decompression) refers to the leaving off of the craniotomy flap during an emergency procedure for evacuating a subdural hematoma or intracerebral hematoma. This decision is made by the surgeon due to very high intracranial pressure (ICP) measured, or the inability to replace the bone flap due to brain swelling.[3-6] This procedure can also be done prophylactically, where the bone is left off to avoid an unexpected raise in post operatively measured ICP.[6]

Secondary decompression (also known as late decompression) is usually performed in patients without surgical mass lesions in whom the intracranial pressure is raised and becomes refractory to maximal medical therapy.[3-6] Surgery to remove a mass lesion may already have been performed in this group. The goal here is to control raised ICP.[6] This is most commonly described after a period of 3 days, but it may be sooner if the guidelines used, so suggests.[3]

Traumatic Brain Injury (TBI) refers to any insult to the brain that is not acquired or degenerative in nature. This insult is caused by an external force and may lead to an altered state of consciousness. This may lead to impaired physical and cognitive functioning.[7] An initial post-resuscitation Glasgow Coma Score of less than 9 is classified as a **severe TBI**.[8]

Effects of decompressive craniectomy on the brain

Decompressive craniectomy reduces intracranial pressure[3 9-11], improves cerebral oxygenation[11-13] and improves cerebral blood flow.[9-11] Cerebral compliance is also increased.[11]

Critical cerebral oxygenation showed immediate reversal after decompressive craniectomy in studies by Jaeger et al.[14] and Weiner et al.[15] This was confirmed when CT perfusion scanning confirmed improved cerebral perfusion, after decompressive craniectomy in adult TBI.[16]

The mechanism by which this happens is thought to be by increasing the size of the "compartment", as defined in the Monroe-Kelly doctrine, and unopposed swelling of the brain is allowed. It is however this unopposed swelling that exposes cerebral tissue and neurons to traction forces and may lead to venous compression or kinking at the bony edges. This may cause secondary injury to an already vulnerable brain.

Intracranial pressure is reduced after decompressive craniectomy with a median of 15mmHg ($p=0.005$) according to Howard et al.[17] Olivecrona and colleagues found a mean decrease in ICP of 20mmHg ($p<0.001$) after decompressive craniectomy.[18] Timofeev et al.[19] showed that decompressive craniectomy lead to a sustained reduction in mean ICP (from 21.2mmHg before decompression, to 15.7mmHg after decompression: $p=0.01$) in all of the 27 patients that they reviewed in 2008. These patients then need a significantly lower mean arterial pressure to maintain cerebral perfusion pressure above 70mmHg after decompressive craniectomy. Intracranial pressure reactivity (PRx) was also positive in all patients in their study after decompressive craniectomy.[19] PRx quantifies the relation between Arterial Blood pressure (ABP) and ICP. If a rise in ABP leads to a rise in ICP – impaired auto regulation- PRx will be positive. Ang and colleagues found that this is associated with a worse outcome in patients with TBI, as it is associated with more secondary ischemic insults.[19] Aarabi et al.[20] confirmed reduction of ICP to less than 20mmHg reliably in 85% of patients that underwent decompressive craniectomy in TBI. They showed mean reduction from 23.9mmHg to 14.4mmHg ($p<0.001$) in their study of 50 patients.[20]

Factors influencing outcomes in decompressive craniectomy

Howard et al.[17] found certain factors that did seem to predict a better outcome after decompressive craniectomy in TBI. Similar to other studies[11,21-23], the presence of unreactive pupils or other signs of brainstem dysfunction on admission correlates accurately with poor outcomes.

Higher admission GCS does lead to better outcomes.[17,24] This finding is supported by Willaims et al.[25], Ho et al.[24] and Guerra et al.[26] Aarabi et al[20]. showed that patients with an admission motor score of 5 or 6, were 4.2 times more likely to have a good GOS at three month follow up.

The presence of smaller pupil size or absence of unilateral dilated pupils, on admission also correlates with better outcomes.[20] Ho and colleagues also found that the absence of a non-evacuated intracranial haematoma were associated with increased chance of delayed neurological recovery, up to 18 months after the injury.[24]

Howard et al. found no correlation between **age** and **associated injuries** in their study of forty patients.[17] Of note however, in a study of 171 patients that underwent decompressive craniectomy, Williams and colleagues found that age did play a role in outcome. In their study the group with a good GOS after six months were younger than the poor outcome group (26 vs. 41 yrs; p=0.0223).[25] Guerra et al.[26] used age of less than 50yrs as the criteria for inclusion in their review of 57 patients that had decompressive craniectomy carried out for severe TBI. Many centres have followed suit and use age of more than 50yrs as exclusion for decompressive craniectomy. Schirmer and colleagues[23] are however worried about the small numbers of patients older than 50 years that are included in studies, and are therefore hesitant to make bold exclusion criteria regarding patients older than 50 years. In studies in children, with small cohorts (n=12 and n=27), that underwent decompressive craniectomy for severe TBI, good outcomes (GOS 4 or 5) are obtained in at least 50% of cases.[27 28]

Timing of decompressive craniectomy does seem to be important. Czosnyka et al.[29] showed that persistently elevated ICP for more than six hours results in worse outcomes. Early decompressive craniectomy had a favourable outcome (GOS 4 or 5) in 78.6% of patients, compared to the 47.1% in patients that underwent secondary decompression in a study by Aarabi et al.[30] Polin et al[31] agreed that earlier intervention (decompressive craniectomy within 48 hours) led to improved outcomes compared to later decompression. Al-Jishi et al., however, compared outcomes between early and late decompressive craniectomies in adults after TBI. They found worse outcomes in the early decompressive group.[5] Worse outcome in early decompression after decompressive craniectomy was also reported by Albanese et al. (18% vs. 38% in the late group).[22] This is ascribed to the associated mass lesions and generally more dire condition of the patients in their study that underwent early decompression.[5] Albanese et al. also found more frequent hypotensive episodes in the early decompressive craniectomy group.[22]

Contrary to the aforementioned studies, Aarabi et al. found no single factor to reliably predict outcomes in their study of 54 patients during a 12 month follow-up period.[30] The authors (Aarabi et al.) also noted no difference in outcome between a well randomised group of patients that underwent monitoring of ICP after surgery, and a group of patients that did not have ICP monitoring after decompressive craniectomy.[30]

Effect of type of procedures for decompressive craniectomy on outcomes

There are three types of decompressive craniectomy in common use, with no uniform agreement on the best technique.[11] Bifrontal decompression is still predominantly used for diffuse brain injuries where the decompression is required to reduce intracranial pressure; several centres do however use a hemi-craniectomy for diffuse injuries as well. Unilateral fronto-temporo-parietal craniectomy is the most commonly used procedure and is especially preferred when a unilateral mass lesion needs evacuation at the same time as decompression, or for lesions with a unilateral pressure effect. Some units do still perform bilateral decompressions where a thin central strip of bone is left over the sagital sinus.

Size of the craniectomy is important in the outcomes of patients.[23 32-34] Authors recommend a cranial defect of at least 12cm[18 35-37] to 15.3cm[30] in diameter. Herniation and strangulation of cerebral tissue occurs if the defect if too small.[16 33] In a study by Jiang et al, published in 2008, it is clear that patients, in whom a limited craniotomy was performed, fared worse than those in whom a standard decompressive craniectomy was done.[38] Reduction of ICP was also more marked in the group that underwent a standard decompressive craniectomy.[38]

Many authors[18 23 32 36 39] are in agreement that **durotomy and duraplasty** is of utmost importance in performing adequate decompression. Olivecrona et al.[18] stated that there is no volume expansion if a duraplasty is not performed.

Measurements of outcome after TBI

Throughout the last 40 years of regular publications on outcomes of decompressive craniectomy, the Glasgow outcome score (GOS)[40] developed by Jennet is still the most commonly used system to measure outcome. In the studies in this review, most reported outcomes by dichotomising outcomes into good and poor outcomes. Good outcomes were defined as GOS 4 and 5, while poor outcomes were 1 to 3.[3-5 11 15 17 20 21 23 25 28 32 37 41-74] This uniform measure of outcome adds greatly to the ease of comparing outcomes, as well as the reproducibility of studies. However, a drawback is the subjective nature of the score. The interpretation of independence is subject to the observer's opinion. There is also more and more emphasis placed on defining functional ability and psychosocial function in rehabilitation. A more objective scoring system such as SF-36 has been proposed by Timofeev and Hutchinson.[11] This scoring system enables the researcher to profile functional well-being as well as mental health and personal attitude of the patient.

Honeybul et al. published on their review of 74 patients in 2011.[48] They applied the CRASH model to pre-operative analysis and triage of their cohort of patients in a prospective fashion.

It was found that the CRASH[75] outcome prediction model, with great accuracy (AUROC 0.905 (95% CI 0.829 - 0.982)),[48] ads a reliable predictor of outcomes in patients after severe traumatic brain injury. The outcomes as measured by the GOS at six months after decompressive craniectomy were similar to that predicted by applying the CRASH model.[48] It may therefore be effective to apply the CRASH model in identifying candidates for decompressive surgery, in the setting of severe traumatic brain injury. This may help to improve the “benefit to burden” ratio.[48 75]

Outcomes after decompressive craniectomy

Studies and case series are published every year on different centre’s outcomes in patients with severe TBI that underwent decompressive craniectomy. This reflects the controversy and interest there is in the salvage of severe TBI patients. However, there is still a lack in conclusive evidence for, or against, decompressive craniectomy as a management option in TBI.

In a summary of studies done between 1971 and 2001, Piek et al.[33] found a cumulative mortality of 30%, poor outcomes (GOS 1-3) of 14.7% and found good outcomes (GOS 4 or 5) in 46% of patients.

Howard et al. studied a cohort of forty patients that underwent decompressive craniectomy after TBI and did a six month follow-up telephonic interview. Twenty four of their patients underwent primary decompressive craniectomy. The mortality rate was 55%, but in the survivors, 12 of the 18 patients (66%) had a good outcome (GOS 4 or 5).[17]

Li et al.[37] did a retrospective review on 91 patients with acute subdural hematoma's after TBI. Fifty one patients had a decompressive craniectomy after evacuation of the hematoma and 40 patients had a craniotomy done only. Outcomes were reasonably similar between the groups, where 42% of the decompressive group had good outcomes (GOS 4 or 5), and 45% of the craniotomy group had good outcomes. Mortality rates were also similar at 38% in the decompression group, and 32% in the craniotomy group. There were however more patients with extra cranial associated injuries in the decompressive group and the bone flap size were larger in the decompressive craniectomy group.[37] Selection bias may therefore play a role in the outcomes.

In general, studies after 1999 shows good outcomes in 26 to 66% of patients, with mortality rates of 14.7% to 52%.[18] [26] The outcomes of studies that reported outcomes after decompressive craniectomy is summarised in **table 1**.

Table 1 : Outcomes of D/C in TBI - summary

Author	Year	Total patients	Good GOS	Poor GOS	Death
Kerr[76]	1968	2			2
Kjellberg and Prieto[76]	1971	50	8	3	39
Ransohoff et al[76]	1971	35	10	4	21
Yamaura et al[76]	1979	154	70	10	45
Gerl and Tavan[76]	1980	30	5	2	23
Gaab et al[77]	1990	37	29	3	5
Polin et al[76]	1997	35	13	14	8
Waltraud Kleist[76] et al	1999	57			11
Guerra et al[26]	1999	57	33 (75%)	11 (25%)	11 (25%)
Munch et al[60]	2000	49	20%	47%	33%
De Luca et al	2000	22	9	9	4
Whitfield et al[78]	2001	26	18 (69%)	2 (8%)	6 (23%)
Schneider et al[79]	2002	62	18 (29%)	30 (48%)	14 (23%)
Jiang et al[38]	2005	241	96 (40%)	80 (34%)	63 (26%)
Albanese et al[22]	2003	40	10 (25%)	13 (32.5%)	17 (42.5%)
Meier et al[80]	2006	117	30 (26%)	40 (34%)	47 (40%)
Aarabi et al [20]	2006	50	20 (40%)	16 (32%)	14 (28%)
Timofeev et al[81]	2006	49	30 (61%)	10 (21%)	9 (18%)
Olivecrona et al[18]	2007	21	15 (71%)	3 (15%)	3 (14%)
Pompucci et al[62]	2007	55	25	9	21
Morgalla et al[59]	2008	33	13 (40%)	15 (44%)	7 (20%)
Howard et al[17]	2008	40	12 (30%)	6 (15%)	22 (55%)
Salvatore et al	2008	80	60	8	12
Kim et al	2009	28	57.1%	42.9%	21.4%
Aarabi et al[30]	2009	52	19	11	22
Stiver et al[82]	2009	170			50%
Ho et al[24]	2011	176	24%	59%	17%
Honeybull et al[48]	2011	74	45	13	16
Ucar et al	2005	100	16%	84%	54%

Despite regular publications on the topic, there have only been two randomised controlled trials studying the benefit of decompressive craniectomy compared to maximal medical management alone, in severe TBI. In a Cochrane systematic review in 2006, Sahuquillo noted that there is no evidence to support the routine use of decompressive craniectomy in adults after TBI.[6]

The first study by Taylor, et al.[28] was performed in children. A small group of patients (n=27) were randomised into a decompression and medical management group. The researchers showed better outcomes in terms of mortality, as well as severe disability, in the early decompression group. This study is however criticised for the small cohort, the fact that childhood outcomes cannot be generalised into adult outcomes and measuring outcomes in childhood TBI is so difficult.[6]

The more recently published randomised controlled trial was by Cooper, et al.[46] This study is the first randomised controlled trial done in adults with a large cohort of 155 patients, evenly randomised into a maximal medical therapy group or a group where decompressive craniectomy is allowed to salvage patients with severely elevated ICP. From this study it was shown that the mortality rate at six month follow-up did not differ between the two groups (19% in decompression group vs. 18% in medical group), and the functional outcome was worse in the decompressive craniectomy group (71% poor), compared to the medically managed group (51% poor outcome)(p=0.02).[46] After adjusting for initial pupil size changes in the study there was no significant difference in the outcomes however. This study is criticised for the high amount of "walkovers" to the decompressive group. This may lead to the patients with a worse injury severity, and therefore higher likelihood of a poor outcome, to be better represented in the decompression group, thereby skewing the randomisation of results. The DECRA research protocol also used a low threshold for intervention to ICP (20mmHg). Brain Trauma foundation guidelines[83] recommend 25 mmHg and an elevation for more than three to six hours as a threshold. The fifteen minutes that is used in the DECRA study seems short. The other critique of the DECRA study is that only patients without any mass lesions were included, the group only performed bifrontal decompressive craniectomies and it appears as if the decompressive craniectomy cohort had more patients with nonreactive pupils than the medical management group (nineteen versus ten).[46] With the criticism as discussed on these two studies there is great need for a large multicentre randomised controlled trial such as RESCUE-ICP that is currently underway, to shed some light on the place for decompressive craniectomy in the management of severe TBI in adults.

Qiu et al.[64] did a prospective randomised trial on 74 patients that was randomised into two groups of 37. They performed unilateral decompression on the one group, and routine craniotomy in the other group after TBI. The study showed an increased reduction of ICP in the group that underwent a decompressive craniectomy, compared to the routine craniotomy group. Mortality at one month review was lower in the group that underwent decompressive craniectomy (27% vs. 57%) and 56.8% of the decompressive craniectomy group had a good outcome, compared to 32.4% in the control group. This study however did not compare medical vs. surgical treatment.

Complications after decompressive craniectomy

Decompressive craniectomy is a major invasive procedure in a severely injured patient. The process of removing skull in an attempt to allow unopposed cerebral swelling does present a number of physiological and physical problems to the brain and surrounding structures. A fourth factor is now added to the equation, namely atmospheric pressure. Previously the cerebrospinous- fluid and venous system in the cerebral circulation have not been exposed to direct atmospheric pressure. Cerebral compliance[11] is therefore increased and the pressure-volume curve is shifted towards the right.[82] This exposure to an external pressure gradient is believed to be a factor in causing the "syndrome of the trephined" that is characterised by positional headaches, nausea and vertigo, with changes in neurological condition and mental ability at times.[11 84] The fact that this, and many of the other complications of decompressive craniectomy, resolves after cranioplasty, supports the theory that atmospheric pressure predisposes to hydrodynamic changes in the patient after decompressive craniectomy.

Various authors[16 17 20 22 25-27 30 48 64 81 82 85] report on complications in their series on decompressive craniectomy. The incidence of subdural hygroma's after decompressive craniectomy is reported in 10 to 26%[24 26 64 82] of patients after decompressive craniectomy, with a study by Aarabi et al.[30] reporting a 50% incidence. The second most common complication of decompressive craniectomy is hydrocephalus in 10 to 33% of patients.[26 82] These two complications both are mostly treated by cranioplasty[11] and the authors recommend early cranioplasty as preventative for these complications. Progression of intracerebral hematoma's is also reported in about 6 to 16% of patients[82]. The most common post operative complication after cranioplasty is however wound infection, with scalp-wound breakdown and bone flap sepsis.[27 82] This leads to prolonged hospitalisation, pain and suffering in the recovering patient. Seizures occur in 7% to 28% of patients after decompressive craniectomy.[24 26] Aarabi et al.[20] reported the incidence of post-cranioplasty bone flap resorption at 50% of cases.

Factors that are identified as increasing the risk of complications are the following:[82]

- Cerebral compliance is increased and cerebrospinal fluid circulation and hydrodynamics is exposed to atmospheric pressure
- Venous drainage may be hindered or damaged by too small a bony opening, that causes kinking, damage and occlusion to the superficial cortical veins
- Larger incisions that allows increased decompression leads to reduced vascular supply to the scalp
- The urgency of decompressive craniectomy might lead to less careful dissection of tissue
- The foreign material that are often used as dural substitutes increases risk of sepsis
- The frontal sinus is often entered in the decompressive procedure, thereby exposing intracranial components to the sino-nasal environment
- Associated traumatic injuries to the scalp and surrounding tissues may predispose to infection

It appears that the single most important factor from the above mentioned studies in reducing the incidence or even preventing complications may be early cranioplasty and proper surgical technique.[16 82 84]

Future research needed

Up until time of this review, the DECRA trial is the only trial done in adult patients after TBI that randomised medical management alone vs. decompressive craniectomy. With the shortcomings of this study as discussed before, there are still unanswered questions regarding the place of decompressive craniectomy in adult TBI. The protocol used in RESCUE ICP holds promise to answer these questions and produce guidelines for management of adults with severe TBI, with respect to decompressive craniectomy.

Conclusion

Decompressive craniectomy does play an important role in the management of severe traumatic brain injury in adults. The outcomes at six months in patients that survive are favourable in 16% to 75% of cases. Complications occur in up to 30 % of cases, but are usually not severe, and can be reduced by performing early cranioplasty and using a meticulous surgical technique.

From the above review it seems as if decompressive craniectomy is a viable option in younger patients (< 50yrs), with admission GCS of more than 4 and without signs of brainstem abnormalities. The RESCUE ICP trial may help to define more conclusive guidelines that will determine the future use of decompressive craniectomy.

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Outcomes of Decompressive craniectomy after TBI in adults – The Groote Schuur Hospital experience

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Abstract

Object. The aim of this study was to assess outcome following decompressive craniectomy in adults with severe traumatic brain injury (TBI) in a South African neurosurgical unit.

Methods. During a 78 month period (January 2005 – June 2011), 76 patients that underwent decompressive craniectomy for TBI in an attempt to lower raised intracranial pressure (ICP) were reviewed. All were older than 14 years and mass lesions were included. Thirty nine point four percent of the patients sustained blunt, low velocity injuries to the head and 19% were involved in motor vehicle accidents. Unilateral hemi-craniectomies were carried out in 81% of patients and 54 (75%) were done as primary decompressive craniectomies. Survivors were followed up for a period of at least six months and functional outcomes were measured using the Glasgow outcomes score. To simplify outcomes the patients were then dichotomised into outcome groups of good (GOS 4 and 5), and poor (GOS 1-3).

Results. At six months follow up 24 patients (33.3%) had a good outcome (GOS 4 or 5) and 48 patients (66.7%) had a poor outcome (GOS 1-3). 32 patients (44.4%) died (GOS 1). There were 16 survivors in the poor group. Sixty percent of survivors had a good outcome after decompressive craniectomy. Eighteen patients underwent secondary decompressive craniectomies and 54 (75%) primary decompressive craniectomies. Mortality was slightly higher in the primary decompression group than the secondary group. Factors that showed significant correlation with outcome were age, admission GCS and good response of ICP to decompressive craniectomy. Complications were encountered in 18% of patients with sepsis the most common (11%).

Conclusion. Decompressive craniectomy was associated with a functional outcome that was better than expected in patients with severe TBI and should still form part of salvage therapy in adults with TBI and elevated ICP.

Key words: Decompressive craniectomy; Adults; Traumatic brain injury; Outcomes

Introduction

Traumatic brain injury (TBI) affects a large number of patients world-wide every year. In the United States it is estimated that 1.4 million people are affected every year with an overall mortality rate of 3.6%.[1] Data from the United Kingdom reports 9 deaths per 100 000 population per year due to traumatic brain injury.[2] The tragedy with TBI is that it usually affects young, otherwise healthy people and causes significant disability. Patients with severe TBI are at risk of developing secondary brain injury due to elevated intracranial pressure that may lead to cerebral hypoxia and necrosis of cerebral tissue, while at the same time a host of inflammatory cytokines are released that are thought to increase brain injury. The Brain Trauma Foundation has been working with leading experts to compile guidelines for the management of traumatic brain injuries. With improvements in prehospital care, neurocritical care and post operative care there has been a steady improvement in outcomes of patients with severe TBI. There is, however, still confusion regarding the place of decompressive craniectomy, as a salvage procedure to decrease intracranial pressure, in TBI patients. Decompressive craniectomy is defined as the surgical removal of cranial bone either unilateral, bilateral or bifrontal and then opening the dura in an attempt to allow unopposed swelling of the brain and may lead to reduced intracranial pressure.[3] Decompressive craniectomy can be further classified into either primary decompression or secondary decompression. Primary decompressive craniectomy is defined as any decompressive craniectomy performed in a patient that is undergoing surgery for primary removal of an intracranial lesion. The aim here is therefore not the control of refractory intracranial pressure (ICP), but to avoid post surgical raise in ICP. The decision is usually made by the surgeon before surgery is undertaken, or at the time of surgery, based on intraoperative findings, and is therefore usually independent of actual ICP measurement.[3 4] Secondary decompression refers to the procedure performed in a patient in whom ICP is refractory to medical management. The aim here is therefore control of high ICP.[3 5] The only undisputed benefit of decompressive craniectomy is that it reduces ICP [6-10] and thereby improves cerebral perfusion pressure with smaller trials supporting evidence that it enhances cerebral oxygenation.[10] There is still uncertainty around the long term effects on functional outcomes in patients with TBI.

Currently there are only two randomised controlled trials published on decompressive craniectomy in TBI. The single trial done on the adult population is the DECRA trial.[9] This study found that decompressive craniectomy does decrease intracranial pressure and reduce length of stay in the intensive care unit, but at a cost of increased unfavourable outcomes.[9] Limitations however of this trial include the exclusion all mass lesions, only bifrontal decompressions were performed, a short time (only 30 minutes) of relative low ICP (20mmHg) as cut off for decompression. The other trial by Taylor, et al.[11] was done in children. This study however included a small cohort of 27 children aged 12 months to 18 years and bitemporal craniectomies were performed.[11] Therefore results cannot be generalised to the general population of adult TBI.

It is the goal of this retrospective case series to add to the literature of studies reviewing outcomes of decompressive craniectomy in adults with TBI, with regards to long term functional outcome if decompressive craniectomy is still a salvage option in the management of increased ICP in severe TBI.

Methods and patients

This is a retrospective case series of all patients admitted from January 2005 up to June 2011 to the division of Neurosurgery at Groote Schuur Hospital, University of Cape Town, South Africa. Patients were identified using a database kept in the Neurosurgical intensive care unit as well as hand searching the operative database. Patients with a severe head injury as indicated by ATLS guidelines[12], a GCS equal or less than 9, and treated by a decompressive craniectomy were included in the study analysis. There are, however, five patients that arrived with initial GCS of more than nine that deteriorated within 24 hours of admission to a GCS of less than nine that were also included. All the patients included were admitted to the neurosurgical ICU and required intubation and ventilation before or after surgery. Patients were managed according to ATLS guidelines and Brain Trauma Foundation (BTF) management protocols[8] were used in the management of traumatic brain injuries. The patients underwent decompressive craniectomy for management of raised ICP – as deemed by the surgeon at time of evacuation of a mass lesion, or after pressure remained elevated (>25 mmHg) for a prolonged period (usually more than 6 hours) on maximal medical therapy as defined and guided in the BTF guidelines[8].

Demographic data of patients included in the study were collected from admission. These included patient age, sex, mechanism of injury, co morbid injuries or illness, type of brain injury and Glasgow coma score (GCS) (Summarised in **Table I**). The ICP and brain tissue oxygenation (PBtO2) was measured after decompression in all patients where primary decompression was performed. There was no ICP data available at time of surgery for all of these cases. Functional outcome was determined at 3 months and 6 months after decompressive craniectomy. The six month outcome measure was decided upon due to difficulty in follow-up of this group of patients, it has to, however, be acknowledged that there may be further improvement in function after this period. Functional outcome was determined using the Glasgow Outcome score (GOS) at out-patient follow-up dates. Patients were assigned a score from 1 to 5 (T**able II**)[13] and outcomes were dichotomised as good (GOS 4 and 5) or poor (GOS 1-3).

The procedure of choice in this series was a fronto-temporo-parietal craniectomy with wide bony decompression (81%). Six bifrontal craniectomies were done and no bilateral decompressive craniectomies were performed. A dural expansion procedure was performed in all 72 cases, a graft was used in 60% of cases, and dural slits used in the remaining 40%. The procedure of dural slits entails making three or four longitudinal incisions in the dura, about 2cm apart, thereby allowing the brain to expand. Wide bony decompressions were performed in all patients. However, no measurements are taken to define the size.

In this report continuous variables are reported as medians, unless stated otherwise and compared using Wilcoxon rank-sum, while proportions were compared using X^2 tests. Statistical analysis was done using GraphPad in Stat® software.

This study was approved by the surgical research committee of Groote Schuur Hospital and the University of Cape Town. Ethical clearance was obtained from the human research ethics committee at University of Cape Town Medical School.

Results

Over a period of 78 months, 76 patients underwent decompressive craniectomy for severe TBI. This equates to 0.02% of the total amount of patients admitted to the neurosurgical service with traumatic brain injuries during the same period (654 admissions of TBI per year).[14] Most patients sustained blunt head injury (39.5%) and 19% of patients were involved in pedestrian vehicle accidents (**Figure I**). Patient ages ranged from 15 to 74 years (median = 28 yrs) and 90% were male. Age was found to have a statistically significant predictive role on the outcome of decompressive craniectomy in TBI. Using and unpaired t-test the median age of the group of patients with good outcome at six months was 22 years, vs. 32 years for the group with poor outcome at the same evaluation interval (p=0.0012). The demographic data is summarised in **Table I**.

At six months follow up 24 patients (33.3%) had a good outcome (GOS 4 or 5) and 48 patients (66.7%) had a poor outcome (GOS 1-3). The poor outcome group included 32 patients (44.4%) that died (GOS 1). There are therefore 16 patients in this group, who survived. This means that 60 % of survivors had a good outcome after decompressive craniectomy **(Table II**). Six month follow up was obtained in all but 4 patients (95%). Eighteen patients underwent secondary decompressive craniectomies with the majority of cases being primary decompressive craniectomies (75%, 54 patients). When comparing GOS outcomes between the group that underwent primary decompressive craniectomy vs. the secondary group, the primary group had a 40% mortality (n=23) with 42% good outcome (n= 19), vs. 33% mortality and a 42% good outcome in the secondary group (**Table III**). 61% of patients who had a primary decompression had a good outcome, while 63% of patients who had a secondary decompression had a good outcome.

Seventeen patients (22%) had associated non-neurological injuries. Using a Fisher's exact test there was no statistically significant influence on outcome.

Admission GCS showed significant difference between the good- and the poor outcome groups (mean 9.25 vs. 7.23; p= 0.0119) with the group of patients with a good outcome having an admission GCS 2 points higher (comparing median values) than the group with a poor GCS. Patients with sharp penetrating head injuries (knife stabs) as well as patients involved in high speed pedestrian vehicle accidents had a worse outcome, with 80% (n=4) and 86% (n= 12) respectively falling in the poor outcome category (Injury aetiology is summarised in **Figure I**). **Figure II** summarises the type of injury sustained and the outcomes at six months.

Fifty three patients (74%) underwent evacuation of a mass lesion (subdural hematoma or intracerebral hematoma) at the same time as the decompressive craniectomy. These patients form 98% of the fifty four patients that received early decompressive craniectomy. The decision to do the decompressive craniectomy in this large group was made at the time of surgery by the surgeon, on the basis of high intracranial pressure as measured after ICP monitor placement, or with severe brain swelling noted during surgery and difficulty closing dura or replacing the bone flap. Eighteen patients in this study underwent secondary (late) decompression.

The intracranial pressure was recorded in 22 patients, prior to decompressive craniectomy. An average reduction in ICP of 18.0 mmHg was measured post decompressive craniectomy (mean of 14.75 mmHg in good outcomes group vs. 10.0 mmHg in the poor outcomes group), with no statistical significance in the effect on outcome as measured by an unpaired t-test. Decompressive craniectomy was not successful in decreasing ICP to less than 25 mmHg in only four patients (5.5%).

Mean time in the ICU on the ventilator was 6.79 days in both outcomes groups. There was no statistically significant correlation determined between sepsis in the ICU (line sepsis, respiratory sepsis or systemic sepsis) and outcome in this study. GOS on discharge from the ICU had a linear correlation of 0.442 (p=0.0002) with outcome at 6 months. In this study all patients older than 58 (n=3) had poor outcomes (GOS 1).

Overall, complications developed in 18% of patients. Wound sepsis and later septic cranioplasty were most common (11%). One patient developed an extradural hematoma 1 day after decompressive craniectomy was done. One patient developed hydrocephalus which required a VP shunt and one patient developed a subdural hygroma that did not require surgical management. Two cases of later traumatic injuries to the unprotected brain occurred – one patient was stabbed with a screwdriver and the other was hit with a hammer.

Discussion

Decompressive craniectomy (DC) was first described by Kocher in 1901 as a method to reduce intracranial pressure. Cushing performed many of these procedures and it subsequently became a procedure in the armamentarium of neurosurgeons to treat elevated intracranial pressure that was refractory to maximal medical therapy.[15] As a procedure to manage intracranial hypertension in the patient with severe TBI, DC has become more popular in the past 15 years with improved ability to measure intracranial pressure (ICP) accurately. Significant progress has been made in the understanding and the management of TBI and in the field of neuro-intensive care, continuing to improve outcomes from the 90% mortality rate, following hemicraniectomy for acute subdural hematomas, that Cooper et al. reported in 1976.[4] Mortality rates have improved since the 1990's where Polin, et al[16] and other studies reported mortality rates of 11 – 23%. Williams et al,[15] in their large study in 2009 reported 33% mortality. The 44% mortality reported in this series is high. When however this is compared to the study by Al-Jishi, et al.[17] where outcome differences were reported between primary and secondary decompressive craniectomies, where mass lesions were more common in the primary group, the high mortality rate is explained.[18-21] As shown in other studies the mortality rate is higher in patients with associated subdural haemorrhage.[17,22,23] In this study the large cohort of low velocity blunt head injury may also be a reason for the high mortality rate. Associated extra cranial injuries were found not to be of any statistically significant prognostic value in this study population. This was also reported by Ucar, et al.[24]

Studies reporting outcomes of patients after decompressive craniectomy for TBI are summarised in **table IV**. The current study therefore reports the fifth largest cohort in the literature. It is however important to look at the differences in the patient injury profile and mechanism of injury, when comparing data on outcomes. TBI is a large heterogeneous group and therefore comparing data is difficult.

In an effort to improve outcomes in TBI and decrease mortality, an attempt was made to identify those factors that are associated with increased benefit when decompressive craniectomy is performed. Age is one such a factor that has been extensively studied. Many studies consider age as a strong exclusion criterion for doing decompressive craniectomy in TBI.[15,39] Upper limits in recommendations vary from as low as 30 years to 50 years in the literature.[15,40,41] In this study all patients above the age of 58 died, it may therefore be reasonable to accept age over 50 as an upper limit when deciding on patients for decompressive craniectomy.[41]

Admission GCS is important in the decision to perform a decompressive craniectomy. Studies by Aarabi, et al.[22,31] as well as Howard and colleagues[42] stated that admission GCS significantly affects outcomes. GCS of 6 and higher shows a 10 % more favourable outcome.[31,40] In this study the admission GCS in the group with a good outcome at six months was a median of 2 points higher than that of the poor outcomes group.

The effect of decompressive craniectomy on the ICP in patients is proven to have prognostic value.[15,21] A greater decrease in ICP after decompressive craniectomy is shown to be a good prognostic sign with a mean reduction of 23mmHg in the good outcome group, compared to 10mmHg in the poor group stated by Williams , et al.[15] in their large study on 171 patients undergoing decompressive craniectomy. This result was supported in this study where a mean reduction of 18mmHg was found in the group with good outcome at six months. Patients with no or little reduction in ICP after decompressive craniectomy all had poor outcomes (n= 5).

Glasgow outcome score is widely used to determine functional outcomes.[13] This scale allows interpretation of a patient's level of independent function and makes this measure objectively assessable. Most of the literature[3, 5, 13, 17 ,19 ,22 ,23 ,31 ,33 ,38 ,39, 43-55] on decompressive craniectomy has used this scale to assess outcomes. This adds an inter-observer comparability to the measures of outcomes. In this study the 24 patients that had a good outcome (33.3% of total cohort, 60% of survivors) compares favourably with other studies that report up to 82% good outcomes in survivors[15] after decompressive craniectomy. An increase in the number of low velocity injuries in this study compared to that in international literature may explain the increased mortality observed (44%, 32 patients). However, it can also be stated that as low velocity injury causes more focal injuries, better outcomes could be expected.

An argument that is often used against decompressive craniectomy is that this procedure allows survival of a larger group of patients that are functionally incapacitated for life, and otherwise (without decompressive craniectomy) would have passed away. Along with data from many other groups[22 ,51 ,56, 57], the fact that 60% of patients that survived in this study had a good outcome proves that this may not be the case.

The shortcomings of this trial need to be noted. The term decompressive craniectomy refers to large decompression of bone either bifrontal or unilateral. As this is a retrospective trial, there is no clear comparison possible between the sizes of craniectomy performed as all were done by the attending surgeon on duty. From the literature it is clear that adequate size of decompression does play a role in outcomes of patients.[58, 59] Measurements of outcomes were also made from patient folders in a retrospective way. This may influence grading of patients.

This is the big drawback with retrospective cohort analysis and the reason why well developed randomised controlled trials are desperately needed in the field of TBI.

Conclusion

The recently published DECRA trial[9] found no clear benefit from performing decompressive craniectomy versus maximal medical therapy in managing severe TBI. As discussed in this article and many editorial comments on the DECRA trial, there is some doubt about the generalisation of their findings. Arguments used by those against decompressive craniectomy in severe TBI are that this procedure reduces mortality but at the same time may increase the poor outcome group (GOS 2 and 3).[60] This places an increased burden on the family and medical system. As can be seen from this study and others like it, there is adults with TBI that do benefit with good outcomes after decompressive craniectomy.

There is still no clear evidence either for or against the use of decompressive craniectomy in management of severe TBI. The RESCUE-ICP trial[44] that is currently underway hopes to clarify the role of decompressive craniectomy in management of TBI.

This and other retrospective trials shows that decompressive craniectomy should still have a role to play in carefully selected patients (young age < 50 years; admission GCS >4/15) with TBI and no brainstem injury signs[39] on admission.

Disclosure

This author has no disclosures to be made. There is no financial benefit or relationship with any company in this trial.

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Table I: Composition of cohort

Total in cohort for analysis	**76 patients**
Lost to follow up	4
Total in study	72
Age	Mean 32.3yrs (15 – 74 yrs)
Gender	89% male; 11% female
Injury etiology	Blunt trauma – 30/72 (42%)
	Pedestrian vehicle accidents - 14/72 (18%)
	Penetrating head injury - 5/72
	Gunshot wounds - 4/72
	Motor vehicle accidents - 3/72
Decompression with evacuation of mass lesion	53/72 (74%)
Craniectomy types	Bifrontal 5/72; Fronto-temporo-parietal 67/72 (93%)
Early decompression (primary)	54/72 (75%)
Late decompression (secondary)	18/72 (25%)

Table II: Study outcome

Summary

Total cohort (n = 72)		
Good	**Poor (GOS 1 - 3)**	
GOS 4 + 5 n = 24 (33.3%)	GOS 2 + 3 n = 16	Death (GOS 1) n = 32 (44%)
Survivors (GOS 2 - 5) (n = 40)		
Good GOS (n = 24) 60%	Poor GOS (n = 16) 40%	

Table III: Outcome summary comparing primary vs. secondary decompressive craniectomy

Total cohort (n = 72)			
Primary decompressive craniectomy		**Secondary decompression**	
Good outcome	**Mortality**	**Good outcome**	**Mortality**
n = 19 (35%)	n = 23 (43%)	n = 7 (38%)	n = 6 (33%)
Survivors		**Survivors**	
61% Good outcome (n = 31)		58% Good outcome (n = 12)	

Table IV: Summary of Literature – Outcomes after decompressive craniectomy

Author	Year	Total	Good GOS	Poor GOS	Death
Kerr[1]	1968	2			2
Kjellberg and Prieto[1]	1971	50	8	3	39
Ransohoff et al[1]	1971	35	10	4	21
Yamaura et al[1]	1979	154	70	10	45
Gerl and Tavan[1]	1980	30	5	2	23
Gaab et al[2]	1990	37	29	3	5
Polin et al[1]	1997	35	13	14	8
Waltraud Kleist[1] et al	1999	57			11
Guerra et al[3]	1999	57	33 (75%)	11 (25%)	11 (25%)
Munch et al[4]	2000	49	20%	47%	33%
De Luca et al	2000	22	9	9	4
Whitfield et al[5]	2001	26	18 (69%)	2 (8%)	6 (23%)
Schneider et al[6]	2002	62	18 (29%)	30 (48%)	14 (23%)
Jiang et al[7]	2005	241	96 (40%)	80 (34%)	63 (26%)
Albanese et al[8]	2003	13	5	5	3
Meier et al[9]	2006	117	30 (26%)	40 (34%)	47 (40%)
Aarabi et al [10]	2006	50	20 (40%)	16 (32%)	14 (28%)
Timofeev et al[11]	2006	49	30 (61%)	10 (21%)	9 (18%)
Olivecrona et al[12]	2007	21	15 (71%)	3 (15%)	3 (14%)
Pompucci et al[13]	2007	55	25	9	21
Morgalla et al[14]	2008	33	13 (40%)	15 (44%)	7 (20%)
Howard et al[15]	2008	40	12 (30%)	6 (15%)	22 (55%)
Salvatore et al	2008	80	60	8	12
Kim et al	2009	28	57.1%	42.9%	21.4%
Aarabi et al[16]	2009	52	19	11	22
Stiver et al[17]	2009	170			50%
Ho et al[18]	2011	176	24%	59%	17%
Honeybull et al[19]	2011	74	45	13	16
Ucar et al	2005	100	16%	84%	54%

Reference list for Table IV

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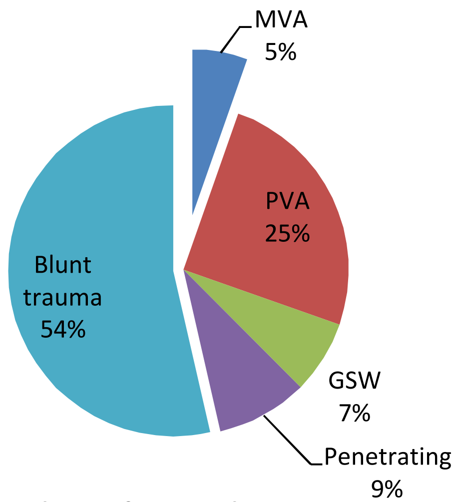

Figure 1: Etiology of TBI in this series

Figure I: Etiology of TBI in study

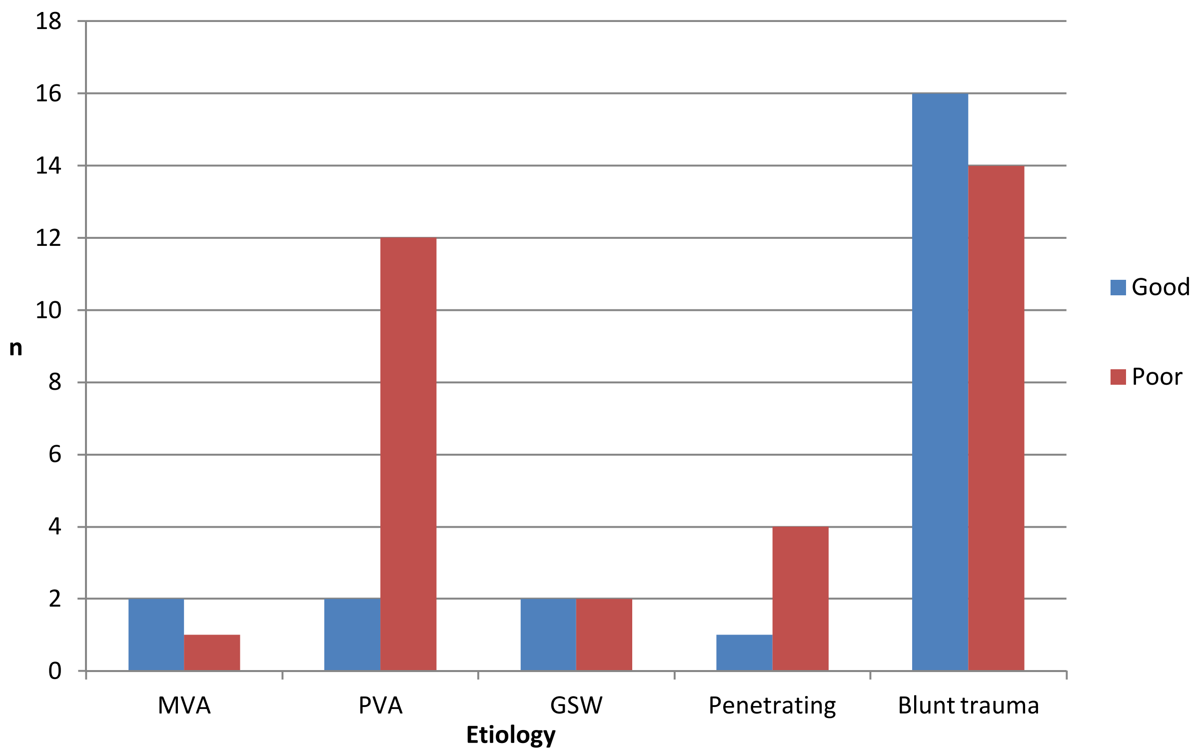

Figure II: Injury etiology vs. outcomes at 6 months

Figure II: Injury aetiology vs. outcomes at 6 months